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Control of Diseases and Insect Pests of Potatoes on Long Island

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PHOTOGRAPH BY F. M. BLODGETT

LOADING A SPRAYING MACHINE

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CONTROL OF DISEASES AND INSECT PESTS OF POTATOES ON LONG ISLAND

M. F. Barrus and C. R. Crosby

Long Island potato growers have large losses every year as a result of insect pests and diseases affecting the crop. These losses may be due to fungi and bacteria which rot the seed pieces before or after planting; the sprouts may rot off from attacks of Rhizoctonia; flea beetles may damage the plants while they are young and again when they are older; leaf hoppers and aphids may become so numerous that they materially affect subsequent growth and yield; virus diseases, such as mosaic, leaf roll, spindle tuber, and yellow dwarf, may occur to a sufficient extent to reduce yields materially; late blight may suddenly appear and destroy the foliage and rot the tubers so that a promising crop becomes a failure; scab may spoil a large proportion of an otherwise excellent crop. Not all of these pests occur in a single field in a given year, it is true, but each of them is present at one time or another, and some of them occur every year, so that an annual loss may be certain as a result of their attacks unless measures are taken to control them. This annual loss materially increases the cost of producing the crop. Much of this loss can be prevented by applying control measures known to be effective. The use of such control measures will enable the grower to produce a crop of better quality at a lower cost per bushel than if they are not used. Of course, other factors, as well as pests, affect yield; nevertheless the application of control measures tends to stabilize production costs and gives the grower some assurance of a normal yield.

This bulletin outlines those control measures known to be effective, and is prepared especially for Long Island potato growers. It does not attempt to supply advice regarding the control of either diseases or insects when such control is imperfectly known.

HEALTHY SEED

The first consideration in the control of potato diseases is the health of the seed tubers; that is, their comparative freedom from virus diseases, such as leaf roll, mosaic, spindle tuber, and yellow dwarf. If the seed is unhealthy, no amount of care in cultivation, fertilization, and spraying will insure a good crop. Time and money spent on these practices will then be largely wasted. Healthy seed at any reasonable price will be cheap as compared with diseased seed. No grower should ever knowingly plant diseased seed.

It is impossible to determine from an examination of the tubers themselves whether they are healthy. Tubers so perfect in shape and conformity

to type and so free from blemishes as to win the first place in exhibitions may yet be badly diseased and thus incapable of producing a profitable crop. On the other hand, small, irregular-shaped, scabby, pitted, and bruised tubers may be healthy and able to produce a profitable crop of excellent tubers. This does not imply that good-looking tubers are unhealthy and poor-looking ones are healthy nor that the latter should be sold as first-class seed; the authors merely wish to emphasize the impossibility of determining the health of the tuber from its appearance. To know whether seed tubers are healthy, one must know whether the vines that produced them were healthy. A careful examination of the field one or more times during the growing season must be made by someone capable of recognizing those diseases that can be carried over in the seed before one can make any definite statement regarding the health of the tubers.

Of course, a potato stock that has produced high yields during a period of years may be assumed to have a satisfactory health record if it comes from the place where it has been produced during these years. If it is grown even for one year at some other place less favorable for seed production, there can be no assurance that it will continue to produce well. Only an inspection of the vines during the growing season can determine whether such assurance can be given. Even then one cannot be absolutely certain, since virus diseases may spread through a previously healthy field without one being able to detect the symptoms that year.

Since most potato growers find it impracticable to visit seed fields in order to select a satisfactory seed source, most of the Northern States and Canadian Provinces have developed an official or semi-official system of seed-potato certification. Under this system the growing plants are inspected by competent disinterested persons, and the product of suitable fields is authorized to be sold as certified seed. The seed troubles of Long Island growers are usually solved in this way. The relative freedom from virus diseases in Long Island fields as compared with the situation fifteen or more years ago attests the value of certified seed. Instances of certified seed with a relatively high content of virus diseases have occurred occasionally, but such instances will become rarer as the certification becomes stricter and more exacting in its requirements and as one understands better the nature of these diseases and the insects that transmit them.

DISEASES CARRIED WITH THE SEED TUBER

Leaf roll

Leaf roll causes dwarfed, rigid, yellowed, low-yielding plants, and an upward rolling of the margins of the lower leaves which are thicker and stiffer to the touch than is normal and the tips of which are lighter in color. Ordinarily, no evidence of the disease is found on the tuber, although a net-

necrosis of the flesh of the tubers from recently affected plants has been observed. The tubers of leaf-roll plants are not infrequently produced on short stolons.

Mosaic

The term *mosaic* includes several distinct diseases, among which are mild mosaic, rugose mosaic, and leaf-rolling mosaic. These diseases are especially noticeable on the Green Mountain and Bliss Triumph groups of varieties. A mosaic is also very common in varieties of the Rural group but is often impossible to detect. The leaves of an affected plant ordinarily are crinkled, distorted, or mottled, depending on the kind of mosaic affecting them and on the temperature to which they have been subjected. The plants are smaller than healthy ones, except in mild cases, and the yield is reduced from 10 to 80 per cent.

Spindle tuber

The disease, spindle tuber, is occasionally observed in potato fields in this State. The affected plants are more erect than are healthy ones; the stems and flower stalks are more slender; and the leaflets are smaller, somewhat twisted, and their margins wrinkled. The tubers are often long and cylindrical and have more eyes than healthy tubers of the same size normally have. In varieties having colored tubers, the affected tubers are lighter in color than are healthy ones.

Yellow dwarf

Plants affected with yellow dwarf are much dwarfed, although plants becoming affected late in the season may be as large as healthy ones. The curled or roughened foliage is a chrome yellow before the stalk dies. The stalk dies from the top downward. On the inside of the upper part of the living stalk and in the tubers are rusty-colored specks which make the disease easy to identify. Often the tubers are small, knobbed, and cracked, and borne tightly against the stem. The diseased hill is almost a complete loss. The disease seems to appear only after a period of high temperature.

Other diseases

In addition to the virus diseases described, two other diseases, black leg and wilt, that occur occasionally in potato fields should be considered in roguing the seed plot. Plants affected with these diseases can usually be detected at the second roguing, and should be removed in that time if not earlier.

Black leg

Black leg, caused by the bacterium *Erwinia caratovora,* affects both the stalks and tubers. It may be detected in the field about blossoming time

by the yellowish color of the foliage, by the erect stark appearance produced by the upward rolling of the leaflets, and especially by the blackened and rotted condition of the base of the stalk. In most cases only an occasional plant is affected, and this stands out clearly in contrast to the green foliage of its healthy neighbors. Tubers from affected plants may show dark areas at the stem end when this is cut away, and these may extend to a soft rotted condition farther within the tuber. Usually affected tubers will show a black or brown or sometimes a straw-colored stem-end rot. During the progress of the disease, the flesh of the tuber becomes transformed to a soft, black, foul-smelling mass.

Wilt

Wilt, caused by the fungus *Fusarium oxysporum,* is a disease in which one or more stalks of a hill show a yellowing and dying of the leaves from the base upward until there is often only a cluster of green leaves at the top. On hot days this yellowing may be preceded or accompanied by a wilting of the leaves and even of the stalks. By peeling away the bark at the base of an affected stalk, one may observe a brown color of the woody part on one side or all the way around. Badly affected plants pull more easily than healthy ones even in the fall after the death of all plants. This is due to the rotted condition of the roots. Some or all of the tubers of affected plants may show a brown or black discoloration of the vessels when the stem end of the tuber is cut away. This condition, which may also be caused by other factors, is known as *stem-end browning.* The yield from wilted plants is usually less than from healthy plants because of the smaller size of the tubers.

SEED TREATMENT

Certain diseases of potatoes, as sprout rot and scurf, scab, black leg, and silver scurf, are caused by organisms that inhabit or are carried on the surface of the seed. These organisms, with the exception of the one causing silver scurf, can be killed by treating the potatoes in solutions or suspensions of mercury compounds. Such a treatment also protects the seed piece to some extent from decay after planting, and thus enables the sprouts to obtain more nearly the full value of the food material contained in the seed piece than if it had rotted early and to develop with less interference or interruption. It has been observed that treated seed on the average gives a better stand, or come-up, and a higher yield than do untreated tubers. There is some indication that treated seed produces a crop of tubers more nearly free from blemishes than does untreated seed, but this is not always true. Seed treatment cannot be depended upon to control common scab nor to control sprout rot completely, since the organisms causing these diseases

occur commonly in the soils of Long Island fields and, when conditions are especially favorable for their development, they will attack potatoes. In up-state New York, in New Jersey, and in many other States, potato seed treatment has proved to be a practicable control measure, and there is some evidence that it may be so on Long Island. It must be said, however, that some experiments and demonstrations of seed treatment on Long Island have not given the increases in yield that have been obtained in up-state New York, but recent unpublished results obtained on the Long Island Research Farm by Dr. H. S. Cunningham are fully as favorable to seed treatment as are those obtained elsewhere. The Long Island crop is usually dug while the soil is yet warm, thus avoiding, to some extent, the formation of Rhizoctonia scurf on the tubers which occurs in soil at cool temperatures.

METHODS

The principal objection raised by Long Island growers to seed treatment is the impracticability of the time-soak method when formaldehyde or corrosive sublimate is used. With the newer instantaneous-dip method, this objection is largely removed. By this method the chemical is simply stirred into water and the seed tubers are dipped into it to wet their surface. Directions for making this treatment are given so that any grower wishing to treat his potatoes may learn how to do it.

The mercury compounds that have been used most commonly in instantaneous-dip treatments in New York State are yellow oxide of mercury and Semesan Bel. Directions are given only for the use of yellow oxide of mercury but they are the same for Semesan Bel except in the amount of the chemical used in proportion to water.

Yellow-oxide-of-mercury treatment

Yellow oxide of mercury is a fine yellow powder. It is rather heavy and settles rapidly when added to water. For this reason the mixture must be stirred frequently to keep the material in suspension. Treatment may be made at any time within a month before planting. No injury has been observed in experiments from the practice of treating cut seed that has been cured after cutting. Probably freshly cut seed should not be treated. During 1932 more than 100,000 bushels of seed potatoes were treated with yellow oxide of mercury in New York State with satisfactory results.

The treatment can be made in a treating machine and, for treating relatively small quantities, one can construct a cheap and simple apparatus that will answer the purpose very well. In using such an apparatus, a half barrel or other wooden container of about the same shape is desirable for holding the treating mixture. A metal container may be used

if painted on the inside with a good coating of asphaltum paint. Another similar tub or pail is useful for making additional mixture, and a wooden paddles needed for stirring the mixture.

Two or more woven-wire (½-inch mesh), flat-bottom baskets with handles should be purchased or constructed which, when set inside the tub, will nearly fill it. This basket should be painted inside and out with an asphaltum paint. A drainboard should be constructed long enough to hold two or more baskets and so located that, when the baskets of treated potatoes are placed on it, the liquid draining from the potatoes will run back into the tub, to prevent waste.

Procedure

One pound of yellow oxide of mercury (technical grade) is added to 15 gallons of water in the tub, and this mixture is stirred vigorously with a wooden ladle until all is in suspension. A basket is filled with seed potatoes, and is then dipped into the liquid, is plunged up and down two or three times, and is turned sidewise at the same time to insure complete wetting of the pieces and to keep the mixture well stirred. The basket of treated potatoes is removed to the drainboard, the mixture in the tub is stirred, another basket is filled, and the operation is repeated. When several baskets are used, they can be left on the drainboard longer and there will be less waste of material than when only two baskets are used. The first basket of potatoes is then dumped into a crate where they will dry.

Additional mixture may be made in the extra tub or pail and may be added to the treating tub as needed. It is essential that the mixture be thoroughly stirred before it is poured into the treating tub as otherwise it will be weak. The yellow oxide is heavy and settles quickly. The mixture does not lose strength and can be used as long as any is left. Fifteen gallons will usually treat 100 or more bushels of seed potatoes. The treatment costs less than 2 cents a bushel for material.

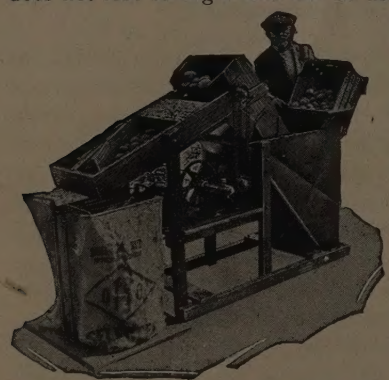

FIGURE 1. A SEED-TREATING MACHINE OPERATED BY AN ELECTRIC MOTOR

For treating several hundred to a thousand bushels of seed, a treating machine (figure 1) is more satisfactory. Hand-operated machines and those driven by an electric motor or gasoline engine are available. The treating mixture used is the same as that already described. The seed tubers are placed in the hopper and come out treated at the other end.

Precautions

Seed potatoes treated with any of the mercury compounds named are poisonous and should not be eaten by man nor animals. In handling such compounds one should avoid breathing the dust.

In experiments conducted on limestone soils of up-state New York and on other soils sufficiently alkaline to favor scab development, the harvested tubers from seed treated with yellow oxide of mercury, as well as those treated with other mercury compounds, were somewhat scabbier than those from untreated seed. Seed treated with formaldehyde gave a crop slightly less scabby than that from untreated seed. It should also be stated that formaldehyde-treated seed gave no increase in yield over the check, while mercury-treated seed did increase the yield somewhat.

DISEASES CONTROLLED BY SEED TREATMENT

Rhizoctonosis

Caused by the fungus *Corticum vagum* var. *solani* (*Rhizoctonia solani*)

Rhizoctonosis affects the tubers, sprouts, and the mature plant. On the tuber, the fungus ordinarily shows as small brown-black bodies closely adhering to the skin but not penetrating it. They may be as small as a pinhead or as large as a half-pea. They may be few in number or the surface may be dotted with them. They are most easily seen when the tuber is washed, for they are almost coal-black when wet. These are the resting bodies (sclerotia) of the fungus and do no harm to the tuber beyond marring its appearance. The fungus may also develop brown threads, or strands, over the surface of the tuber or a portion of it, causing a russet appearance of the skin. The pitting of the tuber, once thought to be due to Rhizoctonia, is now believed to be caused by wire worms, although the fungus may be found in the pits.

Rhizoctonia also produces cankers on the tender young sprouts before they have appeared aboveground. These often surround the sprout and rot it off. This condition is known as *sprout rot* or *sprout canker*. When such a condition occurs, new sprouts are sent up, but these also may become affected. The final result is the failure of these sprouts to appear or their development into weak vines. When not so badly affected, the vines, although appearing late, may yet develop into a productive plant. The sprouts are attacked and rotted in this way by a fine white fungous growth proceeding from the black bodies on the seed tubers. As this fungus is also capable of living in the soil for a long time, the attack of the sprouts may come from the fungus in the soil as well as from the tuber, but experiments indicate that it comes largely from the sclerotia on the seed piece. This explains why seed treatment reduces the amount of sprout rot.

The fungus attacks also the base of older vines and may produce an abnormal appearance, such as the development of aerial tubers in the axils of the leaves, enlarged and purplish stalks, and the production of many small irregularly-shaped tubers at the surface of the soil.

Control consists in treating the seed with a mercury compound, greening the seed so as to promote the early appearance of sprouts, and maintaining a soil rich in humus and in a fertile condition.

Black leg

See page 5 for a description of this disease.

Scab

(Caused by *Actinomyces scabies*)

Scab is caused by a fungus which attacks the skin of the potato tuber, causing roughened areas of various sizes. These areas may be few in number or so numerous as to cover the entire surface of the tuber. The scabbed areas in late-dug potatoes may become entirely eaten away by millipedes so that the original scab cannot be seen. The scab organism is carried through the winter in the soil, in manure, and in the scab spots of the tubers. The growth of the organism is favored by hot dry soil and by an alkaline condition of the soil. It is believed that infection occurs most readily when the tubers are young, provided soil conditions are favorable at that time.

Seed treatment by any of the methods already described is believed to destroy the organism on the surface of the seed tuber. However, even when treated seed or clean seed is planted, scab may develop extensively on the new crop if the soil is alkaline in reaction and the organism is present.

To control the disease, either treated or clean seed should be planted in soil known to be free from the scab organism or in soil sufficiently acid (not more than pH 5.4) to prevent the development of the organism. Soils already acid should produce potatoes relatively free from scab. Soils not very alkaline can be changed to an acid condition by proper management. This includes abundant use of cover crops, the use of acid-producing fertilizers, such as ammonium sulfate for the nitrogen requirement, and the application of sulfur to the soil before planting. Sulfur should be used only when necessary and, then, be applied only to the parts of the field where scab has been troublesome in the past. Finely ground sulfur, such as dusting sulfur or inoculated sulfur, is most satisfactory although ordinary sulfur flour has given nearly as good results and is considerably cheaper. Sulfur should be applied broadcast after the ground is plowed, and should be

harrowed in before the potatoes are planted. The amount required will vary from 200 to 600 pounds an acre, depending on the degree of alkalinity of the soil or on the extent to which the previous crop was scabby. If ammonium sulfate is to be used in the fertilizer, the amount of sulfur may be reduced by one-third or one-half, and, if scab was only slightly troublesome, it can be omitted altogether. Sulfur has not been effective in controlling scab under all conditions, particularly in the heavy types of soil.

Potatoes, while they will tolerate an acid condition sufficient to control scab, will, nevertheless, be adversely affected if the soil acidity is much increased, as will happen if either ammonium sulfate or sulfur is applied year after year. Even a single application will have a residual effect, so that care should be exercised, especially when sulfur is used, to make the application only sufficiently heavy to bring about the desired result. Some other crops, such as legumes, cabbage, and corn, are likely to do poorly following heavy applications of sulfur. Potato growers who have trouble with scab could well afford to have their soil tested from time to time to determine the degree of change needed to make the soil unfavorable for scab development.

Since an alkaline soil condition is favorable for scab development, it is obvious that applications of alkaline-producing substances, such as lime and wood ashes, to a soil that is already alkaline should be avoided. Even nitrate of soda should not be used repeatedly under such conditions. Although all precautions be taken to avoid scab, it will sometimes be troublesome, especially when hot dry soil conditions prevail during the formation and early growth of the tubers.

SPRAYING AND DUSTING

Applications of fungicides and insecticides to the potato vines during the growing season will protect the vines to a large extent from diseases and insects and will enable them to produce a larger crop of tubers free from rot than when the vines are not thus protected. Many experiments have shown beyond any question the value of such applications. It is important, however, that the right kind of materials be used and that they be properly applied if profitable results are to be obtained. Moreover, if the seed is weak and the stand poor, and if the soil is poorly adapted to potatoes, infertile, poorly prepared, or poorly cultivated, neither spraying nor dusting is likely to be profitable or even worth while. Applications of fungicides and insecticides are likely to be valuable when other good practices are faithfully followed.

SPRAYING POTATOES[1]

Material to use in spraying

Bordeaux mixture is the material used throughout the season in spraying to protect the vines from late blight, hopper burn, and flea-beetle injury. Calcium arsenate is added to it when needed to control potato beetle and flea-beetle. Bordeaux mixture is a precipitate formed by mixing a solution of copper sulfate (blue vitriol) with a solution of lime. It should be freshly made; a mixture that has stood for several hours is inferior to fresh bordeaux. Experiments indicate that a 4–2–50 bordeaux is most satisfactory for Long Island.

Making bordeaux mixture

The materials required for making 4–2–50 bordeaux mixture are: copper sulfate (blue vitriol), 8 pounds; hydrated lime, 4 pounds; and water, 100 gallons.

Copper sulfate may be used either in granulated form or as large crystals, but it should be free from foreign matter. A calcium lime that has not become air-slaked is desirable whether lump or hydrated lime is employed. If the latter is used, a form which is extremely fine, is most satisfactory. If magnesium lime is used, a 4–4–50 formula is safest.

Stock copper sulfate

A clean burlap bag containing 40 or more pounds of copper sulfate is suspended in a barrel containing an equal number of gallons of water (40 or more) so that the sulfate is immersed at the surface of the water. The sulfate will dissolve in a few hours or overnight.

Stock lime

The solution of lime is prepared by placing 40 pounds of the hydrated lime in a barrel and adding 40 gallons of water, stirring the mixture thoroughly. The hydrated lime should stand for twenty-four hours or more in the water. Bordeaux mixture can be made by adding the required amount of hydrated lime (4 pounds to 100 gallons of mixture) directly to the screen on the tank and washing it through, although, when made in this way, it contains coarser particles than when the lime is allowed to soak in water first.

Mixing the materials

To make 100 gallons of 4–2–50 bordeaux mixture, a 100-gallon sprayer tank is filled about three-fourths full of water. Then 8 gallons of stock copper-sulfate solution is poured into the tank and stirred, and 4 gallons

[1]The statements regarding spraying made in this bulletin are based on experiments conducted during the past four years in Suffolk County by O. D. Burke and R. B. McCormack and in Nassau County by G. W. Simpson, Henry Menusan, Jr., and William Dickison, all of the Cornell University Agricultural Experiment Station staff.

of stock milk of lime, previously stirred, or 4 pounds of dry lime, is added. The mixture is stirred or agitated. The tank is filled with water. All materials are run into the tank through a V- or cone-shaped bronze or copper strainer with eighteen or more meshes to the inch. If the tank holds more than 100 gallons, the copper sulfate and the lime are increased in proportion.

Poison

Six to 8 pounds of calcium arsenate to each 100 gallons of spray, or 6 to 8 pounds for each acre of potatoes, may be added when bugs are troublesome, usually at the first or at the first and the second applications.

Another method of preparing bordeaux mixture

This handy method of preparing bordeaux mixture used by many Long Island farmers is applicable where running water is available.

The amount of copper sulfate and of hydrated lime required for preparing the quantity of bordeaux mixture of a given strength for a tankful is placed, respectively, in the bottom of separate compartments. The compartment for copper sulfate may be lined with copper sheeting and the one for lime with tin or zinc, if desired. Running water is introduced at the bottom, and, as it rises in the compartments, the chemicals are dissolved and flow out through screen outlets at the top into a common mixing trough and thence into the sprayer tank (figure 2). Before the tank is filled, all of the copper sulfate and all of the lime will have been dissolved or washed through.

Two barrels may be used for this purpose instead of the apparatus shown in the diagram. Screened containers for holding the chemicals (the one for the copper sulfate should be of copper) should be suspended from the top of the barrel and should be large enough to reach nearly to the bottom. An outlet is cut in the side of each barrel near the top and provided with a screen through which the solution is conducted to the mixing trough as described above.

To make 500 gallons of the 4–2–50 bordeaux mixture, 40 pounds of copper sulfate is added to one container and 20 pounds of hydrated lime to the other. Approximately 250 gallons of water may pass through each container, but it is immaterial whether the same amount passes through each so long as enough passes through to dissolve the materials. When spraying for the potato beetle, the required amount of calcium arsenate, 30 to 40 pounds, may be added to the lime compartment with the lime.

Calculation of amounts of materials needed

Approximately an average of 100 gallons of bordeaux mixture to each acre will be used at each application. Thus 8 pounds of copper sulfate and 4

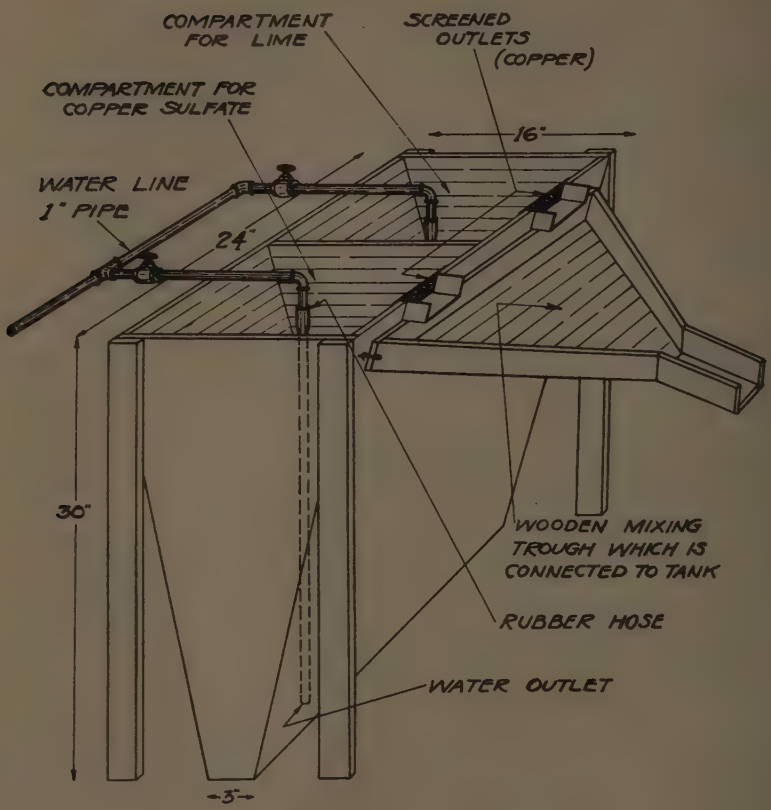

FIGURE 2. APPARATUS FOR MAKING BORDEAUX MIXTURE RAPIDLY

pounds of lime to the acre are needed for each application, and 8 pounds of calcium arsenate at one application or 16 pounds for two. If a man has 50 acres to spray and he will spray four times, 1600 pounds of copper sulfate, 800 pounds of lime, and either 400 or 800 pounds of calcium arsenate will be needed. These materials should be purchased in advance of the time when spraying operations begin and should be kept stored where they will not deteriorate. It may be necessary, however, in order to have the lime in relatively fresh condition—free from air-slacked lime—to purchase it as needed.

Applying the spray

Recent investigations indicate that applications of spray to potatoes on Long Island can be timed satisfactorily to meet the invasions of insects and

diseases and that, by so doing, it is possible to reduce the number of applications that would be required if a regular schedule were followed. Thus, to control the Colorado beetle, one or two applications of calcium arsenate, properly timed, will be required depending upon the time of appearance and the relative abundance of the insects. In the same way bordeaux mixture may be applied only as needed to repel flea beetles and to prevent blight and injury from leaf hoppers. Only three applications may be required during some years while, in others, six or seven may be necessary to obtain satisfactory results. Fewer applications may be required in one section of the Island than in another, and certainly fewer are required for Irish Cobbler than for Green Mountain potatoes. Experiments conducted in Nassau County for the past four years indicate that during that period no great benefit resulted from more than two applications to Cobblers and three to Green Mountains. On the South Shore, where late blight appears perennially, additional applications will be needed.

In order that such a scheme of spraying may be successful, it is absolutely essential that adequate observations of the development of these potato insects and diseases be made throughout the growing season by a competent person and that information regarding measures to be taken be sent promptly to the growers. The cost of such a service should be small in comparison with the saving obtained in the cost of spraying. This service is being furnished by the county farm bureau.

Schedule of applications*

Number of application	Variety of potatoes	Approximate time of application	Material used	Enemy
1	Cobbler and Mountain	When the first Colorado-beetle eggs hatch	4–2–50 bordeaux mixture plus 4 pounds of calcium arsenate for each 50 gallons of spray	Colorado beetle Flea beetle
2	Cobbler and Mountain	A week or two after the first spray	4–2–50 bordeaux mixture plus 4 pounds of calcium arsenate for each 50 gallons of spray	Colorado beetle Flea beetle Late blight
3	Mountain	A week or two after the second spray	4–2–50 bordeaux mixture	Flea beetle Leaf hopper Late blight
4	Mountain	About two weeks after the third spray	4–2–50 bordeaux mixture	Leaf hopper Flea beetle Late blight
5	Mountain	About two weeks after the fourth spray. Not always needed	4–2–50 bordeaux mixture	Leaf hopper Flea beetle Late blight

*Should late blight appear, additional applications with 4–2–50 bordeaux mixture will be necessary.

The first application will be needed as soon as the Colorado-beetle eggs begin to hatch. The second application may be timed to take care of additional hatchings, and is dependent on the rate of hatching and on the

severity of the infestation. A heavy rain shortly after the first application of the spray or a very rapid development of new foliage may make it necessary to spray within a week after the first application, whereas if the first application controlled the beetles, the second application may be made two weeks later and with the bordeaux mixture without the poison. The third application can ordinarily be made two weeks after the second and with bordeaux mixture alone unless the Colorado beetles have not been controlled by previous applications, in which case the application, with poison included, should be made at a shorter interval. It may also be necessary to shorten the interval if late blight appears. The fourth application is made with the same material and for the same reasons as the third and should be timed according to needs. In some cases it may not be necessary. The fifth and subsequent applications are required only in case of continued prevalence of late blight and leaf hoppers.

In spraying Irish Cobblers, a schedule which will control the Colorado beetle is sufficient for all purposes. This is indicated in the first two applications listed in the schedule (page 15).

In following any system of potato spraying, it is essential that the applications be made thoroughly. They should be made with a sturdy sprayer equipped with one to three nozzles to a row and maintaining a pressure of 200 to 400 pounds to the square inch. The nozzles should be adjusted so that the spray strikes the vines with some force and so that there is not much overlapping at the margins of the cones of spray until after the spray has reached the vines (figure 3). They should also be adjusted

FIGURE 3. SPRAYING POTATOES WITH A POWER SPRAYER, NEAR RIVERHEAD, LONG ISLAND

so that all parts of the vines are covered by the spray mixture. Readjustments will be needed from time to time as the vines increase in height and width and when the boom gets out of adjustment. As nozzle disks become worn by the force of the spray so that they are not so effective in forming a satisfactory mist, they should be replaced with new disks. This will ordinarily be needed after each 65 to 75 acres sprayed.

Selection and care of a spraying machine

The first consideration in spraying is a durable machine for applying the spray properly. Several excellent spraying machines are on the market, any one of which will ordinarily give satisfaction. In selecting a machine a grower should consider several factors, among which are the following: size and durability of machine to buy; availability of repair parts; capacity of the machine; ease of adjustment of parts and accessibility to the various parts needing care, adjustment, and repair.

The size of machine to buy will depend upon the acreage of potatoes to be sprayed and to some extent upon the lay of the land. It is not wise to purchase a light machine. A rugged traction machine capable of applying 125 gallons of spray to the acre at a pressure of 250 pounds to the square inch is the minimum requirement that should be considered.

The machine should be rugged. The wheels and axle, especially, should be heavily built. Unless it is well built throughout, there will be more or less danger of breakage during the season, and this usually occurs when one wants to continue spraying. It is better not to economize on the price of a machine at the expense of good construction.

No matter how excellent a machine may be, it is useless when out of commission. One should be able to obtain a replacement for a broken or wornout part either from the dealer from whom the machine was purchased or from the manufacturer within 24 or 48 hours at the most.

The capacity of the machine should be sufficient to maintain easily a pressure of 250 pounds to the square inch with the number of nozzles one wishes to use.

Ease of adjustment of parts and accessibility to the various parts needing care, adjustment, and repair are important. Any special tools required should be of good quality.

The boom should be constructed to provide for variation in number and arrangement of nozzles and be adjustable in a vertical direction so that it can be raised and lowered easily. One should also be able to adjust the nozzles in any direction.

The strainer on the tank should be cone-shaped or W-shaped and not flat, for the flat strainers clog much more easily. A sediment strainer should be fitted to the pipe between the tank-outlet and the pump. This

will save much delay caused by clogged nozzles and will also aid in preventing scoring of cylinders.

The machine should be constructed so as to be well-balanced when the driver is seated, in order to prevent a drag on the horses' necks. Usually the tank is evenly balanced over the axle.

The machine should be adequately lubricated throughout whenever used. The axle bearings may need attention several times during a day's spraying.

After each day's use, the nozzles should be removed and washed in water. Water should be added to the tank and pumped through the machine to flush out the pipes.

At the close of the spraying season, the tank should be cleaned of sediment, the pump and pipes flushed clean, and a light oil (filtered crankcase oil will do) pumped through the machine. The boom should be taken apart and the pipes and nozzles stored in oil. These can be rinsed out in gasoline before they are assembled the next season. The machine should be housed to protect it from weathering. A spraying machine properly cared for will give returns in efficiency of operation, while a poorly cared for sprayer is often worthless.

DUSTING POTATOES

Many growers prefer to apply copper lime dust to their potatoes rather than to use bordeaux mixture as a spray. Dust is practicable if properly applied and may be used in the place of spray in potato fields. When such a dust comes in contact with water, the materials in the mixture go into solution and form bordeaux mixture, so that the material finally left on a dusted leaf is the same as that left by spraying it. If good results are to be obtained, it is necessary that dust be applied frequently and in sufficient amounts and that the application be uniformly and thoroughly made. It will not pay to dust a field that has a poor stand or is making a poor growth any more than it will pay to spray such a field. On the other hand, dust will give considerable protection against insects and blights, and will be profitable when applied to a field that is capable of producing a good yield.

Copper-lime dust

Copper-lime dust may be purchased ready-mixed or the ingredients may be obtained separately and mixed at home. The usual recommendation is to use a mixture of 20 per cent of monohydrated copper sulfate with 80 per cent of lime. When a poison is needed, 20 pounds of calcium arsenate is substituted for an equal quantity of hydrated lime in the mixture.

Formula

For making this mixture, also known as 20–20–60 copper-arsenate-lime dust, one would use 20 pounds of monohydrated copper sulfate, 20 pounds of calcium arsenate, and 60 pounds of hydrated lime. As hydrated lime is commonly put up in 50-pound sacks, it is more convenient to dump a sack of lime into the mixer and then add enough of the other materials to make the right proportion. When this method is followed, one uses 50 pounds of hydrated lime with 17 pounds of monohydrated copper sulfate and 17 pounds of calcium arsenate. If a poison is not needed, one uses 50 pounds of the lime with 12½ pounds of monohydrated copper sulfate.

Mixing the dust

A dust mixer should be purchased or made at home out of a tight barrel or steel drum. After the correct amount of each material has been placed in the container, the mixer should be turned for three or four minutes at the rate of 20 to 30 revolutions a minute. It is important that the ingredients be thoroughly mixed. The mixing should be done where there is a good circulation of air. It is advisable for the operator to moisten a piece of cheesecloth and to tie it over his nose and mouth to breathe through, or to use a respirator.

Mixed material, if kept for a time, should be stored in a clean, dry, tight can, and the cover kept on tight. The can containing monohydrated copper sulfate should always be kept tightly covered, except when taking the material out. The sacks containing hydrated lime should be kept tight and dry. Year-old lime or lime left exposed to the air for a considerable time should not be used. The lime used should be a hydrated lime. The use of magnesium hydrated lime (finishing lime) has given satisfactory returns. The monohydrated copper sulfate should be dry, finely pulverized, free from lumps, and should have a white color with a faint bluish tint. When it has a gray, a drab, or a brownish color, it is not satisfactory.

Applying the dust

The first application should be made as soon as the plants are well up, and others at intervals of ten to fourteen days as recommended for the spraying period. Applications should be made when the vines are wet and when the air is quiet. The night or early morning usually provides these conditions, although the latter time is preferable because the bordeaux mixture formed on the wet leaves soon dries and adheres to the surface. An examination of the vines should be made before dusting is started in order to determine whether they are wet enough.

Copper-lime dust should not be applied when the foliage is dry, as it is not then effective and is therefore wasted.

The dust machine should apply dust uniformly over the plants and envelop them in a cloud. Two nozzles to a row are necessary and three are better. A power machine gives better distribution than a traction machine. For small areas, a fan type of hand duster is satisfactory by going over each row twice, especially when the vines are large. When using a hand-duster, the operator should wear high-topped boots to protect his legs from the copper dust.

It will require 37½ pounds of the 20-per-cent dust to be equivalent in copper sulfate to 100 gallons of a 5–5–50 bordeaux mixture. As 100 gallons of bordeaux are needed at each application to each acre of potatoes when the vines are large, at least this quantity of dust will be needed to give equal protection. When bugs are troublesome, 20 pounds of calcium arsenate should be substituted for an equal amount of the lime. The poison may not be needed after the bugs have disappeared.

DISEASES AND INSECTS CONTROLLED BY SPRAYING AND DUSTING

Late blight

(Caused by the fungus *Phytophthora infestans*)

Late blight is one of the most dreaded potato diseases because it can cause extensive losses in a short period of time. During hot dry seasons it rarely appears, but in wet seasons it may become very prevalent. On Long Island it may appear as early as June, but in up-state New York it rarely shows until late July or August when the nights are cool.

Late blight shows on the leaves as dark water-soaked areas which rapidly enlarge, often involving the entire leaf in one to four days. A white mildew appears over the diseased area on the underside of the leaf, and it is by this that the disease can be positively identified. This is especially prominent when the air is very moist.

On the tubers the disease appears as irregular discolored areas that later become somewhat sunken. Within the flesh of the potato, a reddish brown dry rot is produced which, in the initial stage, does not extend inward beyond the straw-colored ring of conducting vessels. The diseased tissue is often invaded later by bacteria which bring about a foul-smelling soft rot.

The causal fungus overwinters in the affected tubers. If these are planted, the resulting plant is often attacked by way of the seed piece. The fungus finds its way to the surface of the ground through the diseased sprout, on which it fruits, producing spores in abundance. From this source of infection, spores are blown by the wind to neighboring plants and fields where they bring about the blight.

Late blight occurs during wet weather, especially when the night temperature drops to 50° F. or lower and the days are warm. Spore produc-

tion, dissemination, and germination take place only under moist conditions. In years when there is abundant moisture in the form of rain, fog, or heavy dews, particularly in the latter part of the season, the disease becomes epidemic.

Control

The vines should be sprayed thoroughly with 4–2–50 bordeaux mixture or dusted with 20–80 copper-lime dust. The first application should usually be made when it is necessary to apply poison for the potato beetle. The insecticide can be added directly to the spray or dust mixture. Applications should be made often enough to cover and to protect the new growth, which will ordinarily be about every two weeks. When there is danger from blight, they should be made more frequently. Applications made before rainy periods are more effective than when made after them. Three nozzles may be needed to a row, especially during the later applications, in order to do a thorough job. At least 100 gallons of the spray mixture or 35 pounds of the dust mixture are needed to an acre when the vines are large. Applications should be continued late in the season. The horses and wheels will not injure the vines as much as will late blight. Wheel injury can be materially reduced by the use of vine spreaders and by covering the rim of the wheel with discarded casings of automobile tires (figure 4).

Although thorough applications of a fungicide will control late blight, it is also well to avoid planting tubers showing any rot. Potatoes from blighted fields should not be dug until the vines are dead and dry. If the vines are badly blighted and there is evident danger of tuber rot before frost, the vines may be killed by spraying them with a copper-sulfate solution made by dissolving 15 pounds in 100 gallons of water. Potatoes from affected fields should be stored in a moderately warm place for a week or two in order to enable one to sort out the rotted ones. The balance should then be stored in a cool place. The nearer the temperature is to 37° F. the better they will keep.

Early blight

(Caused by the fungus *Alternaria solani*)

Early blight is principally a disease of the leaves, occasionally affecting the stalks and tubers. By destroying the leaf tissue, the disease causes a reduction in yield of tubers. On the leaves, it occurs as dark brown or black, oval or angular spots which may show a series of concentric ridges that give them a target-board effect. At first the spots are small but after the leaf is weakened or dead, or even before, the spots may enlarge to a diameter as great as ½ inch. These areas usually appear first on the older, lower, and less vigorous leaves, and may be so numerous as to cause the leaf to die.

FIGURE 4. THE WHEEL RIMS OF THE SPRAYER ARE COVERED WITH OLD AUTOMOBILE TIRES

If the wheel rims are covered with old automobile tires, less injury is done to the vines and roots of the plant

The leaves above may become similarly affected until finally only a few green spotted leaves at the top of the plant remain. Spots may likewise develop on the leaf stems and on the upper parts of the stalks.

Early blight is caused by a fungus which produces large, dark-colored spores on either the lower or upper surface of the affected areas. These spores are capable of remaining alive over winter. The fungus mycelium also can pass the winter in old affected vines and produce a crop of spores the following spring.

The spores are disseminated mainly by the wind. A relatively high temperature with abundant dews or rainy weather and weakened plants bring about a condition most favorable for the production of spores and for infection. Epidemics of early blight may occur when late blight is absent, but the disease is not nearly so important.

Control

Early blight is not so easily controlled as is late blight, but frequent applications of 4–2–50 bordeaux mixture beginning when the plants are young and continuing at ten-day intervals throughout the growing period, will often hold the disease in check and sometimes control it entirely.

Colorado potato beetle

(*Leptinotarsa decemlineata* Say)

The adult Colorado potato beetle passes the winter in the ground, usually several inches from the surface. The beetles emerge from their winter quarters just before early planted potatoes come up and are ready to attack the plants as soon as they appear aboveground. After feeding on the potato foliage for a few days the female beetle begins to deposit her orange-colored eggs on end in masses on the underside of the leaf. The eggs are not all laid at one time but in successive batches. The egg-laying period for each female is from four to six weeks. The eggs hatch in three to seven days, and the young larvae, or slugs, begin at once to feed on the foliage. The larva becomes full-grown in ten days to three weeks and then enters the ground for pupation. After a pupal period of five to ten days, the transformation of the adult takes place but the beetles do not emerge to lay eggs for the second brood of slugs until the latter part of July. Fortunately, the second brood is usually not so destructive as the first; the beetles are not so abundant and the plants being larger are more able to withstand attack.

Control

The Colorado potato beetle can be controlled by using 8 pounds of calcium arsenate in 100 gallons of bordeaux mixture for the first one or two applications of the regular spray schedule. To obtain the best results, the poison should be applied when the eggs begin to hatch. About 100 gallons of the spray material should be applied per acre, using sufficient pressure and the proper arrangement of nozzles to thoroughly cover the plants. It should be remembered, however, that increasing the amount of poison in the mixture will only in part make up for using too small a quantity of spray material per acre or for faulty methods of spraying.

Timely spraying is essential for beetle control because the newly hatched slugs are more easily poisoned than are the larger ones and they are destroyed before much damage is done. Many failures to control the beetles are the result of waiting too long before applying the poison.

If a dusting schedule is followed, the mixture should contain 20 per cent of calcium arsenate for beetle control.

Potato flea-beetle
(*Epitrix cucumeris* Harris)

The potato flea-beetle is about 1/16 inch in length and nearly black in color. The adults hibernate under trash and appear in early spring to feed on a great variety of plants before the potatoes come up. The beetles migrate to potato fields in great numbers as soon as the plants appear above ground. In feeding, the beetle makes an opening in the epidermis of the leaf and then eats out the pulp, but leaves the epidermis on the opposite side of the leaf intact. Later this bit of epidermis dries out and may break away, leaving a small hole through the leaf. In this way the leaves are often riddled with holes and some of them are killed.

After feeding on the leaves for some time the beetles enter the soil to deposit their eggs near the roots. The larvae feed on the underground parts of the plant and may sometimes tunnel just under the surface of the tuber. The larvae pupate in the soil, and the beetles of the new brood become abundant the middle of July. These beetles are much more numerous than those of the spring brood but the plants are larger and more able to withstand attack. Nevertheless, they may cause significant injury to the foliage.

The injury caused by flea-beetles may be prevented to a considerable degree by keeping the plants well covered with bordeaux mixture during the period when the beetles are most numerous. This is especially important when the plants first come up and are being attacked by the overwintered beetles. Calcium arsenate is usually applied in the first or in the first and second sprays for the control of the Colorado potato beetle and undoubtedly aids in protecting the plants from flea-beetle attack. The feeding habits of the flea-beetles is such as to enable a large proportion of them to escape the poison. It is therefore a question whether it pays to use the poison in July when the summer brood of flea-beetles make their appearance. It is not the usual practice to use the poison at that time but to rely on the deterrent action of the bordeaux mixture.

Potato leaf-hopper
(*Empoasca fabae* Harris)

The potato leaf-hopper is a small, slender, green or yellowish insect about 1/10 inch in length, found mostly on the underside of the leaves. When disturbed they spring quickly into the air, make a short flight, and disappear under the leaves of another plant. The young hoppers, or nymphs, are pale greenish in color and resemble the adult in general appearance, but lack wings. When disturbed they move with a peculiar sideling motion.

The injury caused by the leaf-hopper to potatoes is known as *hopper-*

burn. The injury first appears as a slight yellowing of the tip of the leaf. The edge of the leaf then turns brown, curls upward, and dries out, becoming brittle. The injury spreads from the margin towards the center of the leaf, thus leaving the base and an area along the midrib green after the edge has been killed. In severe cases the foliage is destroyed and the plants are killed. In some seasons the loss caused by the leaf-hopper is greater than that inflicted by all other insects and diseases attacking the potato.

The adult leaf-hoppers hibernate under trash and emerge early in the spring. They feed for a time on a great variety of weeds and cultivated plants. Common dock is a favorite spring food plant. Early beans also attract large numbers of the insects. Usually the hoppers do not migrate to potatoes in any great numbers till the middle of June. The adults are to be found on the underside of the leaves where they deposit their minute greenish eggs in the larger veins and in the leaf stems. The eggs hatch in a week to ten days and the young pale greenish nymphs appear on the underside of the leaves. The nymphs pass through five stages and acquire wings at the fifth molt. In the last stage the nymph is about 1/10 inch in length; the head and the thorax are pale green and the abdomen is yellow. In warm weather the nymphs reach maturity in about two weeks, but towards the end of the season when it is cooler three weeks are required. Two full generations and a partial third and fourth brood usually develop each season. As the adults deposit eggs over a period of two months or more the different generations greatly overlap so that in August the adults of three broods may be ovipositing at the same time. This is the period when the insects reach their greatest abundance on the potatoes and when hopper-burn injury develops most rapidly. Breeding continues on potatoes till the plants are killed by drouth, blight, or frost and the surviving adults are driven to other plants or go into hibernation.

Control

Thorough and careful spraying with bordeaux mixture at intervals of about ten days is the most effective means of controlling the potato leaf-hopper. Both the adults and nymphs die within a day or two when feeding on leaves well covered with bordeaux. They are sucking insects and feed exclusively on the plant juices which they extract from the leaf by means of the needle-like bristles of their mouthparts. It is believed that they are killed by the copper in the leaves derived from the covering of bordeaux mixture. At any rate, regular and careful spraying with this material is an effective and practical method of keeping the hoppers under control and will materially increase the size and quality of the crop. Dust-

ing with copper-lime dust gives slightly less control of leaf-hoppers than does spraying with bordeaux mixture.

Potato aphids

The pink and green potato aphis (*Macrosiphum solanifolii* Ashmead)

The spinach aphis (*Myzus persicae* Sulzer)

Long Island potatoes are subject to attack by two kinds of plant lice. The most destructive species is the pink and green aphis although whenever a serious outbreak occurs the spinach aphis is almost sure to be present to a greater or less extent.

The pink and green aphis may pass the winter either in the egg stage on the twigs of cultivated roses or as lice on one of its green food plants. On Long Island it usually winters in the egg stage, but in mild winters may survive as lice. It has a large number of summer food plants, including potato, tomato, pepper, spinach, and peas, as well as many weeds.

On Long Island the winged forms usually appear on the potato about the middle of June. When once established on the potato the lice may multiply rapidly so that, under favorable weather conditions, the plants may become heavily infested in three or four weeks. The lice are to be found on the underside of the leaves, on the growing tips and on the blossom clusters. The leaves curl and die and the whole plant may be badly stunted or killed outright. Outbreaks of the lice are likely to be more severe in seasons of drouth, and heavy driving rains are beneficial in washing off and killing the lice.

Control

The potato aphis can be controlled by dusting with a 3-per-cent-nicotine–lime-dust. This is a rather expensive operation and should not be undertaken unless the lice threaten to seriously injure the crop. At least 30 pounds of the dust to the acre should be applied. To be effective the dust must be confined around the plants by means of a canvas trailer. This consists of a sheet 30 or 40 feet long and wide enough to cover the rows treated. It is attached to the back of the duster above the outlets and is dragged over the potato plants. To obtain satisfacory results, the work should be done on a quiet day when the temperature is 80° F. or above.

Good results have also been obtained by spraying with 1 pint of nicotine sulfate in 100 gallons of water in which 6 pounds of potash fish-oil soap has been dissolved. It is necessary that the spray is applied with a sprayer giving a pressure of at least 300 pounds and with 3 nozzles to the row. The application should be made on a quiet, warm day, and care taken to adjust the nozzles so as to hit the lice.

In general, dusting has been found to be the more practical method of control.

Potatoes and Camels

THE homely spud, and the ungainly camel, it is said, exemplify better than any other objects the truth of the old adage, "handsome is as handsome does."

The potato is an earthen-like mass, with no claims to beauty in form and color; yet it has become a basic and tasteful food wherever it is grown. The camel stands for all that is ungraceful among the beasts that serve man, but he serves efficiently wherever he can live—and he can subsist and exist in some pretty tough places.

Potatoes do best, other things being equal, where they are given most care and attention.

If you want to know more about the culture and care of potatoes, perhaps the following pamphlets will interest you.

Better seed for commercial vegetable growers (E 122) *Work*
Potato diseases and their control (E 135) *Barrus and Chupp*
Potato growing in New York (E 239) *Hardenburg*
The control of diseases and insects affecting vegetable crops (E 206) *Crosby and Chupp*

They are free for the asking and can be obtained from

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